

## ADDITIONAL FOSSIL VERTEBRATE TRACKS IN NATIONAL PARK SERVICE AREAS

VINCENT L. SANTUCCI<sup>1</sup>, ADRIAN P. HUNT<sup>2</sup>, TORREY NYBORG<sup>3</sup> AND JASON P. KENWORTHY<sup>4</sup>

<sup>1</sup>National Park Service, McLean, VA 22101; <sup>2</sup>New Mexico Museum of Natural History, Albuquerque, NM 87104;

<sup>3</sup>Department of Earth and Biological Sciences, Loma Linda University, Loma Linda, CA 92354;

<sup>4</sup>National Park Service, Geologic Resources Division, McLean, VA 22101

**Abstract**—Fossil vertebrate tracks were first inventoried from National Park Service areas in 1998 and vertebrate tracks ranging in age from the Pennsylvanian through Pleistocene/Holocene were identified in 19 National Park Service areas. Since the completion of that initial inventory, fossil vertebrate tracks have been identified in nine additional NPS areas, for a total of 28 NPS areas preserving fossil vertebrate tracks. The new discoveries include five additional parks with Mesozoic tracks (Aniakchak National Monument, Denali National Park, Manassas National Battlefield Park, Navajo National Monument and Wupatki National Monument) and four with Cenozoic tracks (Agate Fossil Beds National Monument, Chickamauga and Chattanooga National Military Park, Golden Gate National Recreation Area and Oregon Caves National Monument). These new discoveries include the first evidence of Cretaceous dinosaurs in western Alaska (Aniakchak National Monument) and well-preserved claw marks in cave sediments of Oregon Caves National Monument. This paper also highlights new information regarding fossil tracks in parks identified in the initial 1998 inventory including a highly unusual trackway morphology recently discovered in Grand Canyon National Park, a potentially new ichnotaxa from the significant Copper Canyon tracksite in Death Valley National Park and one of the oldest Mesozoic tracksites in North America from Zion National Park. All together the rich fossil record of vertebrate ichnites in National Park Service areas include tracks of amphibians, ornithischian and saurischian dinosaurs, birds, artiodactyls, perissodactyls, carnivores and proboscidiens. Continued research into the vertebrate ichnofossils of National Park Service areas will undoubtedly contribute additional discoveries and increased knowledge regarding these important paleontological resources.

### INTRODUCTION

An initial inventory of fossil vertebrate tracks from areas administered by the National Park Service was undertaken in 1998 (Santucci et al., 1998). During the original inventory the fossilized tracks of ancient vertebrates were identified in nineteen different units of the National Park Service. This ichnological record in the parks ranged from Pennsylvanian trackways in Grand Canyon National Park, Arizona, through Pleistocene / Holocene tracks in Zion National Park, Utah.

Since the original inventory, fossil vertebrate tracks have been documented in nine additional National Park Service areas. These include Mesozoic vertebrate tracks at Aniakchak National Monument, Alaska; Denali National Park, Alaska; Manassas National Battlefield Park, Virginia; Navajo National Monument, Arizona; and Wupatki National Monument, Arizona. Additionally, Cenozoic vertebrate tracks have been documented at Agate Fossil Beds National Monument, Nebraska; Chickamauga and Chattanooga National Military Park, Georgia and Tennessee; Golden Gate National Recreation Area, California; and Oregon Caves National Monument, Oregon. These additional vertebrate ichnites result in a total of 28 National Park Service areas identified with fossil vertebrate tracks (Fig. 1).

### PALEOZOIC TRACKSITES

#### Introduction

Santucci et al. (1998) reported on Paleozoic vertebrate tracks from two National Park Service areas, Grand Canyon National Park, Arizona and Glen Canyon National Recreation Area, Utah. Since the original inventory, no new parks were identified containing Paleozoic vertebrate tracks.

#### Grand Canyon National Park, Arizona

A previously undescribed and highly unusual trackway was recently discovered in the Pennsylvanian Coconino Sandstone at Grand

Canyon National Park (C. Bowman, personal communication, 2006). The trackway was found by Dr. John Whitmore (Cedarville University) in the eastern portion of Grand Canyon. The trackway is contained in a downdropped slab and will be collected. The trackway shows overlapping pairs of manus and pes impressions of very large tracks (16 – 18 cm). The large tracks consist of didactyl pairs, which are not previously known from the Paleozoic (Fig. 2). The tracks may reveal actual morphology of the unknown track-maker, but more likely the shape is due to non-preservation of the lateral digits. The track slab also exhibits a smaller tetrapod trackway and appears to have a few tail drags posterior to the large didactyl tracks.

Of particular interest, the new trackslab shows excellent preservation of sediment splays or fans posterior to the individual tracks. These appear to consist of the sediment (sand) grains that have been pushed posteriorly as the individual feet impact and withdraw from the ground surface. The sediment splay patterns for the manus are small semicircles with an approximate diameter one half the length of the manus impression. The sediment splay patterns for the pes are larger in size and sediment volume and form a “L-shaped” distribution. This sediment distribution is interesting in that it shows angulations that appear to coincide with the oblique gait of the large quadrupedal trackmaker. The sediment splays associated with the tracks may yield valuable information related to the sediment substrate

### MESOZOIC TRACKSITES

#### Introduction

Santucci et al. (1998) reported on Mesozoic vertebrate tracks from twelve National Park Service areas including: Arches National Park, Utah; Big Bend National Park, Texas; Canyonlands National Park, Utah; Capitol Reef National Park, Utah; Colorado National Monument, Colorado; Dinosaur National Monument, Colorado and Utah; Gettysburg National Military Park, Pennsylvania; Glen Canyon National Recreation Area, Utah; Grand Canyon National Park, Arizona; and



FIGURE 1. Map of National Park Service areas that have documented fossil vertebrate tracks. White dots indicate parks identified during the original vertebrate tracks inventory (Santucci et al., 1998). Black dots indicate new parks identified in this paper. 1. Agate Fossil Beds National Monument, Nebraska; 2. Aniakchak National Monument, Alaska; 3. Arches National Park, Utah; 4. Badlands National Park, South Dakota; 5. Big Bend National Park, Texas; 6. Canyonlands National Park, Utah; 7. Capitol Reef National Park, Utah; 8. Chickamauga / Chattanooga National Military Park, Georgia and Tennessee; 9. Colorado National Monument, Colorado; 10. Death Valley National Park, California; 11. Denali National Park and Preserve, Alaska; 12. Dinosaur National Monument, Colorado and Utah; 13. Gettysburg National Military Park, Pennsylvania; 14. Glen Canyon National Recreation Area, Arizona and Utah; 15. Golden Gate National Recreation Area, California; 16. Grand Canyon National Park, Arizona; 17. John Day Fossil Beds National Monument, Oregon; 18. Manassas National Military Park, Virginia; 19. Mojave National Preserve, California; 20. Montezuma Castle National Monument, Arizona; 21. Navajo National Monument, Arizona; 22. Oregon Caves National Monument, Oregon; 23. Petrified Forest National Park, Arizona; 24. Pipe Spring National Monument, Arizona; 25. Rainbow Bridge National Monument, Utah; 26. Scotts Bluff National Monument, Nebraska; 27. Wupatki National Monument, Arizona; 28. Zion National Park, Utah.

ation Area, Utah; Petrified Forest National Park, Arizona; Pipe Spring National Monument, Arizona; Rainbow Bridge National Monument, Utah; and Zion National Park, Utah. Five new parks have been identified with Mesozoic fossil vertebrate tracks and are presented below. In cases where new data, discoveries, or other information related to fossil vertebrate tracks within parks that were previously reported by Santucci (1998), this new information is also presented.

#### Aniakchak National Monument, Alaska

During a paleontological resource survey at Aniakchak National Monument in 2002, a hadrosaur (duckbilled dinosaur) footprint (Fig. 3) was found within the tidal flat or near shore deposits of the Upper Cretaceous Chignik Formation along the Aniakchak River. In addition to the footprint, two “hand” (manus) prints may also be present. This fossil is significant, not only because it represents the first evidence of dinosaurs found within Aniakchak, but because it represents the first evidence for Cretaceous dinosaurs in western Alaska, some 1,290 kilometers (800 miles) from the well-known North Slope dinosaur localities (Fiorillo, 2002). The track also indicates the excellent potential for more dinosaur fossils both within Aniakchak and within the Chignik Formation in general. As part of the Aniakchak paleontological resource survey, a CD-ROM has been created (Koch and Santucci, 2002) with additional information about the track and hadrosaurs in general. Fiorillo (personal communication, 2003) also reports the discovery of additional dinosaur footprints in the Chignik Formation. In addition, 13 upright tree stumps, a large quantity of leaf litter and some leaves with evidence of insect herbivory were found (T. Fiorillo, personal communication, 2003).



FIGURE 2. Unusual new vertebrate track slab from the Coconino Sandstone in the eastern portion of Grand Canyon National Park, Arizona.

#### Arches National Park, Utah

A paleontological resource inventory at Arches National Park identified a number of new vertebrate track localities in the park (Swanson et al., 2005). Tridactyl tracks occur in the Late Triassic Chinle Formation from the southern margin of the park along the state highway. Two theropod tracks and many other tracks have been found within the Jurassic Kayenta Formation in the park. These tracks occur in deposits that have been interpreted as interdunal oases deposits. An isolated reptile track (*Dromopus*?) was identified in the Salt Wash area of the park (Swanson et al., 2005).

A small theropod trackway, unusual feeding traces and subaqueous crocodile tracks are also found within the Ruby Ranch Member of the Cedar Mountain Formation (Early Cretaceous) (Swanson et al., 2005). Lockley et al. (2004) reports tridactyl theropod tracks, didactyl theropod tracks and sauropod tracks as well as tracks from ornithischian dinosaurs from within Arches National Park. Some of these tridactyl tracks may have been made by the coelurosaur theropod *Nedcolbertia*. The didactyl tracks may be attributable to dromeosaurs (*Deinonychus*?). The sauropod (possibly *Pleurocoelus* or *Venenosaurus*) trackways are similar to the classic “wide-gauge” sauropod trackway *Brontopodus*. The two types of ornithischian tracks were likely made by an ornithomimid (potentially cf. *Tennontosaurs*) and an ankylosaur (possibly *Sauropelta*), respectively. The lower track-bearing surface contains a much less complex assemblage of theropod tracks and what may be sauropod track underprints (Lockley et al., 2004). Theropod tracks on this surface display two morphologies, one narrow-footed and the other, a more common morphology suggesting a medium-sized theropod.

#### Colorado National Monument, Colorado

Intensive paleontological resource inventories were initiated during the past five years yielding nearly 75 paleontological localities within Colorado National Monument. At least 79 theropod tracks identified as



FIGURE 3. Cretaceous hadrosaur track from the Chignik Formation at Aniakchak National Monument, Alaska.

the ichnogenus *Grallator* were reported from five localities in the Upper Triassic – Lower Jurassic Wingate Sandstone within the Monument (King et al., 2004). Trujillo and Walker (2005) also report several localities with numerous theropod tracks in the Wingate Sandstone. Lucas et al. (2006, fig. 4C)) reported a manus imprint identified as *Pteraichnus* from the Summerville Formation of Colorado National Monument.

Lockley and Foster (2006) reported on fossil vertebrate tracks from two horizons in the Upper Jurassic Morrison Formation at Colorado National Monument. The tracks occur in fluvial sequences of the Salt Wash Member. The tracks include a theropod, small ornithomimid dinosaur (ichnogenus *Dinehichnus*) and turtles (ichnogenus *Chelonichnium*) (Lockley and Foster, 2006). A few isolated sauropod pes casts are reported from the Salt Wash Member in the Monument (Foster and Lockley, 2006). Sauropod and theropod tracks were reported by Trujillo and Walker (2005) from the Salt Wash Member at Colorado National Monument.

#### Denali National Park and Preserve, Alaska

On June 27, 2005, a tridactyl dinosaur track (Fig. 4) was discovered in a Cretaceous unit at Denali National Park. The track was found by a student from the University of Alaska, Fairbanks, participating in a geology and geophysics field camp held in Denali. The footprint is a cast within coarse sandstone of the lower Cantwell Formation. The rock unit represents a fluvial sequence including alluvial fans, braided streams and some lacustrine deposits (Phil Brease, personal communication, 2006). The track morphology indicates a theropod dinosaur track-maker from the Late Cretaceous of Alaska.

During August 2005, the footprint was measured, photographed and molded. The track-bearing block was carefully removed and transported to be placed on display for the public. This discovery will likely prompt further paleontological field work in the Cantwell Formation at Denali.

#### Gettysburg National Military Park, Pennsylvania

Santucci et al. (1998) reported on the occurrence of *Atreipus* dinosaur manus and pes in the building stone of the South Confederate Avenue bridge over Plum Run. In 2006, additional footprints were reported from other stones in the same bridge (J. Jones, personal communication, 2006). A single *Anchisauripus* track and a possible poorly preserved *Otozoum* track were confirmed by the authors.



FIGURE 4. Theropod dinosaur track from the Cretaceous Cantwell Formation in Denali National Park and Preserve, Alaska.

#### Manassas National Battlefield Park, Virginia

Vertebrate ichnofossils are known from the Triassic Bull Run Formation (“Balls Bluff Siltstone”) within Manassas National Battlefield Park, Virginia (Kenworthy and Santucci, 2004). These ichnofossils include *Gwyneddichnium majore* (Weems and Kimmel 1993). The *Gwyneddichnium* tracks were collected in the early 1990s by Weems during geologic mapping in and around Manassas. The tracks themselves were collected under permit and are currently at the U.S. Geological Survey headquarters in Reston, Virginia (R. Weems, personal communication, 2004). Gore also collected *Gwyneddichnium majore* tracks from Manassas, although they were identified as *Rhynchosaurooides* (Gore 1988a, 1988b). In 1992, an additional track (referred to *Grallator* sp.) (Fig. 5) was found along the banks of Bull Run Creek near Manassas (Weishampel and Young 1996). This has recently been reassigned to *Atreipus milfordensis* (R. Weems, personal communication, 2004).

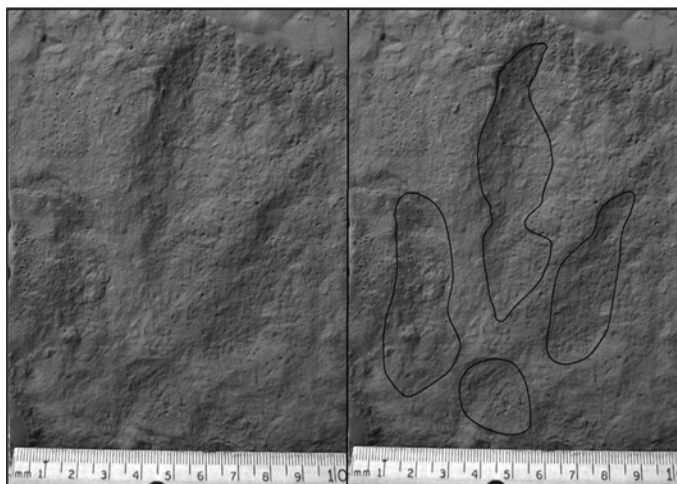


FIGURE 5. Tridactyl dinosaur track from the Triassic at Manassas National Military Park, Virginia.

### Navajo National Monument, Arizona

Two tridactyl tetrapod tracks (Fig. 6) are preserved in blocks of Jurassic Navajo Sandstone at Navajo National Monument, Arizona (Hunt et al., 2005). Santucci et al. (1998) originally reported that the tracks were found in 1933, about a mile from the Keet Seel archeological site. Mellberg (personal communication, 2005) indicated that the tracks probably originated from a site about 10 miles outside the monument boundary near Tall Mountain.



FIGURE 6. Tridactyl vertebrate tracks within blocks of Jurassic Navajo Sandstone on display at Navajo National Monument, Arizona.

### Petrified Forest National Park, Arizona

Tetrapod tracks are identified from three localities at Petrified Forest National Park, Arizona (Hunt, et al., 2005). The first track locality is within a sandstone in the Teepees area of the park. Martin and Hasiotis (1998) report this unit as the Monitor Butte Member of the Chinle Group, while Heckert and Lucas (2002) refer to this unit as the Blue Mesa Member. Several pedal impressions of *Rhynchosauroides* sp., indeterminate swimming traces and an indeterminate large trackway (Santucci and Hunt, 1993; Santucci et al., 1995; Martin and Hasiotis, 1998). A dinosaurian track from this locality represents a right pes impression identified as *Grallator* sp. (Martin and Hasiotis, 1998; Hunt et al., 2005).

The second locality is in the Rainbow Forest area of the park from the Agate Bridge Bed of the Sonsela Member of the Chinle Group (Hunt et al., 2005). The ichnofauna includes *Rhynchosauroides* sp., cf. *Grallator* and *Brachychirotherium* sp. (Martin and Hasiotis, 1998; Hunt et al., 2005).

Martin and Hasiotis (1998) report another vertebrate track locality in the Flattops area of the park. The tracks at this locality are indeterminate, medium-sized reptile tracks. The track-bearing unit is in the Agate Bridge Bed of the Sonsela Member of the Chinle Group (Hunt, et al., 2005).

### Wupatki National Monument, Arizona

The Early-Middle Triassic Moenkopi Formation is extensively exposed at Wupatki National Monument, Arizona. Kirby (1987) reports amphibian swimming traces from the Moenkopi Formation at Wupatki National Monument. In 2003, geologic intern K. Alden Peterson began to investigate the occurrence of vertebrate trace fossils within Wupatki National Monument. During June of 2004, Alden discovered a vertebrate track locality that included large *in situ* *Chirotherium* tracks. Part of the locality included tracks observed in some down-dropped blocks adjacent to the *in situ* tracks. In addition to a *Chirotherium* trackway (Fig. 7), approximately twenty track large archosauromorph-like tracks along with some smaller tetrapod tracks were discovered at the locality (Peterson, 2004; Hunt et al., 2005).

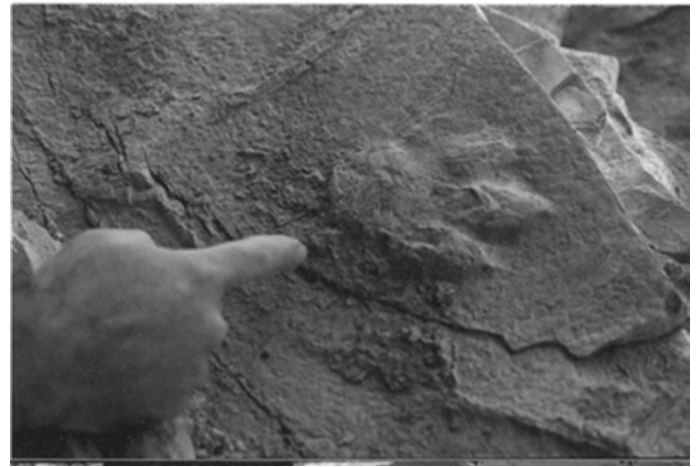


FIGURE 7. Tridactyl track tentatively referred to as “cf. *Tapripeda* n. sp.” from the Miocene Copper Canyon Formation at Death Valley National Park, Nevada.

### Zion National Park, Utah

During 2002 and 2003, staff from the Utah Geological Survey intensified paleontological field activities coordinated by the National Park Service since 1997 in Zion National Park. Through this work over 120 new fossil localities were documented in the park, including many new vertebrate track sites (DeBlieux et al., 2005).

An important vertebrate track locality was discovered in the Early Triassic Moenkopi Formation within the Kolob Canyon District of Zion. Small reptile and possible therapsid (mammal-like reptile) tracks were found in a gray siltstone unit below the Virgin Limestone Member of the Moenkopi Formation. This locality may represent one of the oldest Mesozoic tracksites in North America (DeBlieux et al. 2005).

Additional vertebrate track localities were located in all three members of the Late Triassic – Early Jurassic Moenave Formation exposed in Zion National Park. The basal Dinosaur Canyon Member contains primarily tridactyl dinosaur tracks. The Whitmore Point Member contains large numbers of dinosaur tracks and trackways (Smith and Santucci, 1999; Smith et al., 2002; DeBlieux et al., 2003). The three-toed dinosaur tracks are assigned to the ichnogenera *Eubrontes* and *Grallator*. Tracks appear concentrated in a greenish-gray dolomitic bed in the Whitmore Point Member (DeBlieux et al., 2005). The uppermost member of the Moenave Formation is the Springdale Sandstone. Dinosaur tracks are

rare in this unit and may actually occur at the contact with the overlying Kayenta Formation.

The Early Jurassic Kayenta Formation has the greatest concentration of fossil vertebrate tracks in Zion National Park. The ichnogenera of the Kayenta are primarily *Eubrontes* and *Grallator*. One four-toed track was also located in the Kayenta Formation at Zion National Park (DeBlieux, et al. 2005).

Santucci (2000) reported several dinosaur footprints from the Early Jurassic Navajo Formation along the trail to Observation Point in Zion Canyon. A second vertebrate track locality was located in the Navajo Sandstone near Parunuweap Canyon. The prints of several different animals are preserved on a weathered surface of a large rock-fall boulder (DeBlieux et al., 2005).

## CENOZOIC TRACKSITES

### Introduction

Santucci et al. (1998) reported on Cenozoic vertebrate tracks from seven National Park Service areas including: Badlands National Park, South Dakota; Death Valley National Park, California; John Day Fossil Beds National Monument, Oregon; Mojave National Preserve, California; Montezuma Castle National Monument, Arizona; Scott's Bluff National Monument, Nebraska; and Zion National Park, Utah. Four new parks have been identified with Cenozoic fossil vertebrate tracks and are presented below. In cases where new data, discoveries, or other information related to fossil vertebrate tracks within parks that were previously reported by Santucci (1998), this new information is also presented.

#### Agate Fossil Beds National Monument, Nebraska

A number of tracks are visible in vertical profile at Agate Fossil Beds National Monument (Hunt, 1992; M. Hertig, personal communication, 2002). The vertical profile tracks are documented at Carnegie Hill, University Hill and at the *Stenomylus* Quarry. A wayside exhibit panel along the Fossil Hill Trail suggests these tracks may have been made by entelodonts.

#### Chickamauga/Chattanooga National Military Park, Georgia and Tennessee

Nine caves have been documented at Chickamauga/Chattanooga National Military Park (Sanatucci et al., 2001). Many caves are cut into the limestones associated with Lookout Mountain, some of which have entrances outside park boundaries, however, the subsurface features of the caves may extend into the Park. The Bangor Formation (Mississippian) and Mont Eagle Formation are two Paleozoic limestones exposed in the park. Both formations are prominent throughout the park and contain numerous large pits.

Two caves, Kitty City and 27 Spider, are solution caves in the Cumberland Plateau Cave Area. Kitty City Cave has casts of big cat paw prints and claw marks on the walls. Preliminary assessment of the fossil remains suggests the cats apparently fell into the pit, attempted to climb out, and subsequently died. 27 Spider Cave is located three miles (5 kilometers) north/northeast of Kitty City Cave and is the longest cave in the park with a 1,000 foot (305 meter) passage. The lower part of the cave was mapped by the National Speleological Society. 27 Spider Cave contains a large cat skull and vertebral column which are partially exposed in a mud bank. There are also felid canines exposed in the cave wall. In 1995, a large oil spill in the park forced the closure of all of the caves (D. Curry, personal communication, 2001).

#### Death Valley National Park, California

Death Valley National Park preserves four Cenozoic track localities within its boundaries. All three track localities are preserved within fluvial-lacustrine deposits associated with Cenozoic tectonics that down-

dropped the present day Death Valley and uplifted the Black and Funeral Mountains. Tracks consist of bird and mammal tracks preserved in fine-grained lacustrine sediments usually found associated with shoreline features such as ripples, raindrops and mudcracks.

The most abundant and diverse locality in the Park for bird and mammal tracks is within the Copper Canyon Unit (CCU) where lakeshore deposits preserve twelve *Avipeda*, five *Felipeda*, five *Ovipeda*, three *Hippipeda*, one tridactyl track "cf. ?*Tapirpeda* n. sp.," (Fig. 8) and one *Proboscipeda* ichnospecies (Santucci and Nyborg, 1999). These tracks are especially important because they represent a diverse fauna of large terrestrial mammals, many of which have no known body counterparts in the immediate area. In addition, the CCU preserves a unique record of lake dynamics in association with animal behavior. The CCU sequence includes over 3000 meters of lake basin sediments. New age constraints taken from three interstitial volcanic flows confirm that the CCU was deposited approximately between 6 to 3 Ma, with track bearing units deposited approximately between 5 to 4 Ma (Nyborg and Buchheim, 2005). Due to the number of tracks, (literally hundreds exposed within the lacustrine facies of the Copper Canyon basin) and over sixty track site localities known thus far, there is a unique opportunity to study the variations among these tracks and track bearers. There is also the opportunity to set a standard for description of mammal tracks in the fossil record.

Within unnamed sediments near Cow Creek very large avian tracks (*Avipeda*), a panel with three carnivore tracks (*Felipeda*) and two types

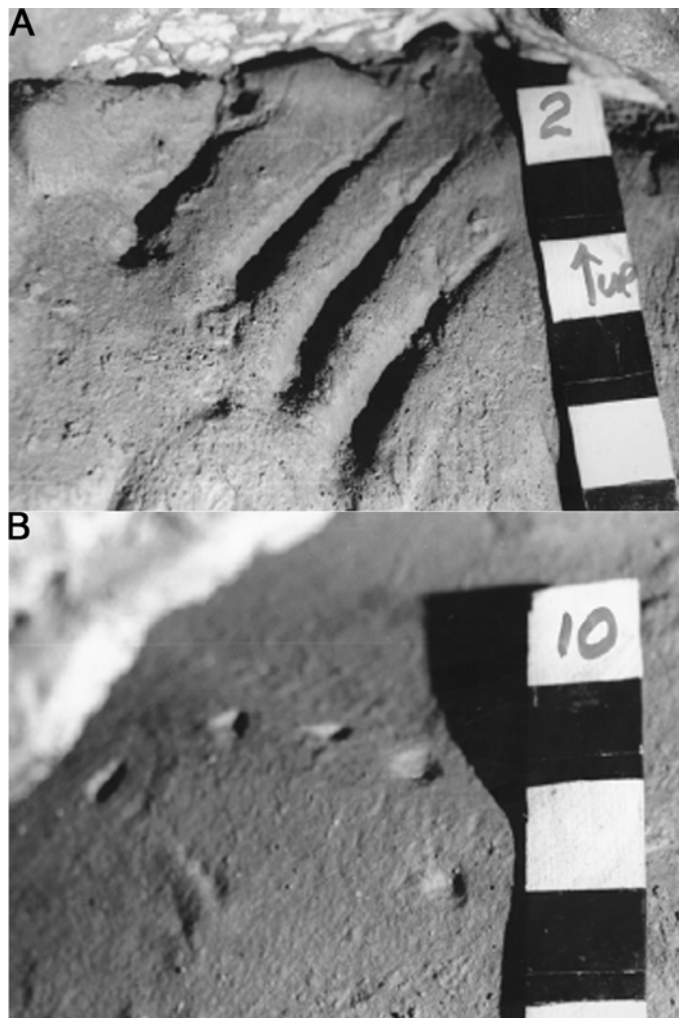


FIGURE 8. Bear claw and scratch marks in cave walls at Oregon Caves National Monument, Oregon.

of artiodactyl tracks (*Ovipeda*) are preserved along several bedding planes representing intermittent fine-grained lacustrine sediments within an overall medium-grained sandstone unit (Santucci and Nyborg, 1999). Although the age of this track locality has not been determined, it appears to be contemporaneous with the Copper Canyon Track Locality due to its similar track fauna.

Also within unnamed sediments an isolated outcrop in the Central Death Valley Playa near Salt Creek preserves avian, artiodactyl, perissodactyl and possible proboscidian tracks (D. Curry, personal communication, 1998). The track-bearing unit is contained within fluvial-lacustrine deposits in an overall conglomerate unit.

Two poorly preserved artiodactyl tracks within lacustrine sediments believed to be associated with the Furnace Creek Formation were collected from Twenty Mule Canyon Track Locality in the 1980s. No additional tracks have been found in this region however this discovery reveals the potential of the region, which is dominated by fluvial-lacustrine deposits.

Cenozoic fossil vertebrate tracks can be found outside of the boundaries of Death Valley National Park however the abundance, diversity and most importantly the quality of preservation of these tracks within the park surpass all other track localities in North America and perhaps the world. The mammal tracks of Death Valley can be biostratigraphically applied, greatly enhancing our knowledge of Cenozoic mammal and bird evolution in southwestern United States and in the reconstruction of the depositional and tectonic history of this playa-lake environment within the context of the Cenozoic basin and fill deposits of Death Valley.

#### Golden Gate National Recreation Area, California

Hunter et al. (1984) report moderately well preserved bilobate depressions probably formed by split-hoofed ungulates and excellently preserved pawprints probably formed by canids. Claw impressions in some of the tracks reinforce the canid identification.

#### Oregon Caves National Monument, Oregon

Vertebrate trace fossils have also been documented in Oregon Caves. A single 4.5 inch (11 centimeter) bear paw print is preserved in the cave sediments. There are at least 20 distinct claw scratch marks in the sediments, tentatively identified as bear claws. One such trace is exceptionally preserved, showing five claw points pushed into the mud (Santucci, et al, 2001) (Fig. 8A-B).

#### TRACKSITE MANAGEMENT AND PROTECTION

Fossil vertebrate tracks and trackways are generally fragile resources and typically studied and maintained *in situ*. Natural conditions and processes, such as weathering, erosion, freeze-thaw temperature changes, will act directly upon surficially exposed *in situ* vertebrate ichnofossils. Such conditions will contribute to the deterioration and eventual destruction of these surficial trace fossils.

Growing scientific and public interest in fossil vertebrate tracksites is paralleled by the increasing documentation of their theft and vandalism. During 2001, over two dozen incidents of either theft or vandalism of *in situ* fossil vertebrate tracks were documented (Santucci, 2002). These incidents range from damages resulting from poor or inappropriate casting techniques to the unauthorized collecting of tracks in units of

the National Park Service. A well-known dinosaur tracksite in a Utah state park was vandalized by members of a Boy Scout group and received considerable national and local media attention. Fossil vertebrate tracks are becoming more visible on the commercial fossil market.

The management and protection of *in situ* fossil vertebrate tracksites has become challenging. Human impacts to vertebrate ichnofossils include incidents of damage or destruction through intentional vandalism, casual theft and systematic theft. Sound management and protection strategies employed for *in situ* fossil vertebrate tracksites include: tracksite inventories, site mapping, photodocumentation, track replication, specimen collection, site stabilization, burial, site closure, construction of maintenance barriers / fencing and a variety of site monitoring strategies.

#### CONCLUSIONS

Continued paleontological fieldwork and research in National Park Service areas will likely yield new occurrences of fossil vertebrate tracks in the future. A new Cenozoic fossil vertebrate track locality has been identified directly adjacent to the boundary of Lake Mead National Recreation Area. The fossil producing unit is well exposed in Lake Mead and future field inventories may yield the presence of similar vertebrate tracks in the recreation area (M. Kissel-Jones, personal communication, 2003). The Eocene Green River Formation is extensively exposed in Colorado, Utah and Wyoming. Fossil vertebrate tracks, including large concentrations of bird tracks and a few mammal track localities, are known from various nearshore and shallow water facies of the Green River Formation. One possible reptile swimming trace was discovered at Fossil Butte National Monument, Wyoming, and is in the park collection. A bird track slab was discovered in a quarry located just outside Florissant Fossil Beds National Monument. This specimen was on loan and exhibited at the monument for a short time. The specimen is now in the collections at the Denver Museum of Natural History (H. Meyer, personal communication, 2006).

New track localities are also likely to be discovered in parks that these resources are already identified. The extensive exposures of late Paleozoic deposits in Grand Canyon, Mesozoic exposures in Glen Canyon National Recreation Area and the Cenozoic lacustrine track-bearing deposits of Copper Canyon in Death Valley National Park, will all like yield new vertebrate ichnofossils in the future.

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